FUNDAMENTALS OF SMOKE ABATEMENT

By J. F. Barkley

* * * * * * * * * * **Information Circular 7588**

UNITED STATES DEPARTMENT OF THE INTERIOR
Oscar L. Chapman, Secretary
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James Boyd, Director

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by

J. F. Barkley[1/]

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1/ Chief, Fuels Utilization Branch, Bureau of Mines.

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INTRODUCTION

Continuous requests for Bureau of Mines Information Circular 7090, "Some Fundamentals of Smoke Abatement," since its publication in 1939, has made it desirable to revise the publication to include developments to date. During the past 10 years, particularly since the close of the last world war, the general public has taken greatly increased interest in the prevention of air pollution. The problem has much in common with that of having unpolluted water, milk, drugs, and food, but it is more complicated.

The public desires pure water, expects the city to provide pure water, is willing to pay for pure water, and expects to continue to pay for it indefinitely; it is a development of civilization. It is, doubtless, correct to say, however, that people in general do not yet understand the detriment of air pollution to their well-being. The fact that a person takes in perhaps 10 times more pounds of air per day than water is given no thought. In city smoke-abatement work, the public, as represented by the mass of small householders, is the hardest to handle. It is rather difficult to assemble a group of people in a room without the air becoming contaminated with smoke from a combustion devised to be incomplete. Even if automobiles continuously give out poisonous gases from incomplete combustion, no consideration is given to limiting their use on city streets. Although the desire for cleanliness, nondestruction of property, and better visibility has been a forceful factor in advancing the work, smoke abatement will continue to lag unsatisfactorily because of indifference to or the lack of fear of polluted air under all ordinary circumstances.

MODEL ORDINANCES

Enough group desire in many cities for better air has resulted in development of methods and schemes for attacking the problem. An ordinance must be passed to give authority to the program. Much work has been done on model ordinances. In 1924, a basic ordinance was prepared by a committee of representatives of the American Society of Heating and Ventilating Engineers, the Stoker Manufacturers Association, the American Civic Association, the American Society of Mechanical Engineers, and members at large. This ordinance has probably served in the past as a reference in the development of many city smoke ordinances in this country. For historical record purposes, its reprinting from Mechanical Engineering, American Society of Mechanical Engineers, May 1924, pages 303 to 305, follows:

Proposed Standard Smoke Ordinance

"AN ORDINANCE regulating the emission of smoke from any chimney, smokestack, or other source within the corporate limits of the city of _____, creating a Bureau of Smoke Regulation, constituting its personnel, and prescribing penalties for the violation of the provisions thereof.

"Sec. 1. Be it ordained and enacted by the City of _____, in Council assembled, and it is hereby ordained and enacted by the authority of the same, that there is created a Bureau of Smoke Regulation, the chief of which shall be known as _____.2/

"The Mayor shall appoint a _____2/ at a salary not to exceed _____per annum. The person so appointed shall be an engineer qualified by training and experience in the theory and practice of the construction and operation of steam boilers and furnaces, also in the theory and practice of smoke abatement and prevention.

2/ May be Bureau Chief, Superintendent, Smoke Commissioner, or Chief Smoke Inspector.

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"The _____3/ may upon the recommendation of the _____,2/ appoint _____4/ at a salary not to exceed _____per annum. The person or persons so appointed shall be engineers qualified by training and experience in the theory and practice of the construction and operation of steam boilers and furnaces and the firing of furnaces.

"The _____3/ may appoint such other inspectors and employees in the Bureau of Smoke Regulation as may be necessary for the proper performance of the work of the said Bureau at such salaries as may be fixed by _____.5/

"The Mayor shall appoint an Advisory Board of _____ engineers, who shall act as advisers on engineering questions to the _____,2/ Bureau of Smoke Regulation. The Advisory Board shall act as a board of appeals, as provided in Section 4 of this ordinance. The members shall serve without pay except when acting as a board of appeals, when they shall receive the sum of _____ each per meeting.

"Sec. 2. 'Persons' shall be considered as referring to all individuals, partnerships, or associations other than corporations.

"'Corporations' shall be considered as including all bodies corporate, joint stock companies or associations, domestic and foreign, their lessees, assignees, trustees, receivers, and other successors in interest having any of the powers or privileges of corporation not possessed by individuals, partnerships, or unincorporated associations.

"'Chart' shall be considered as referring to the Ringelmann Smoke Chart, as published and used by the Bureau of Mines.

"'Stack' shall be defined as including chimneys, smokestacks, structures, and openings, of any kind whatsoever, capable of emitting smoke. Smokestacks on locomotive roundhouses shall be deemed parts of locomotives beneath them for the time being.

"'Advisory Board' shall be considered as referring to the Board of Engineers appointed by the Mayor to act as advisers on engineering questions to the Bureau Chief, Bureau of Smoke Regulation of the City.

"Sec. 3. The production or emission within the City of Smoke, the density or shade of which is equal to or greater than No. 3 of the Ringelmann chart, from any stack, except that of a locomotive or steamboat, for a period or for periods aggregating two (2) minutes or more in any period of fifteen (15) minutes, and the emission of such smoke from any locomotive or steamboat for a period or for periods aggregating one (1) minute or more in any period of eight (8) minutes, is hereby prohibited.

"Sec. 4. No person or corporation shall construct, install, reconstruct, alter, or repair any furnace, boiler furnace, stack, or other apparatus connected with stack, unless he or it shall make application in writing to the Bureau of Smoke Regulation on the form furnished by the said bureau, duly sworn to before a notary public or any person authorized to administer oaths, for a permit for such construction, installation, reconstruction, alteration, or repair and in and by such application shall give the plans and specifications, showing the style and dimensions of the furnace, boiler furnace, stack or other apparatus connected with a stack intended to be used, a description of the building or part thereof in which such furnace, boiler furnace, or other apparatus is located, including the means provided for regulating the temperature of such building or part thereof and ventilating the same, and generally all provisions made for preventing smoke, together with a statement of the

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3/ The Mayor or other authority designated by him or by the Council.
4/ May be Deputy or Assistant with any of the designations in 2/.
5/ Usually the Council.

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kind of fuel proposed to be used and of the operating requirements to be made of the furnace or furnaces referred to therein, and unless such application shall be passed upon by the Bureau of Smoke Regulation, and approved in writing and a permit issued as hereinafter provided; provided, however, that minor or emergency repairs which do not increase the capacity of such furnace, or which do not involve any substantial alteration in such furnace, boiler furnace, stack, or other apparatus, and which do not involve any alteration in the method or efficiency of smoke prevention, may be made without a permit.

"Any application shall be approved or rejected within ten (10) days after it is filed in the office of the Bureau of Smoke Regulation.

"Upon the approval of any application, a copy of which shall be left on file in the office of the Bureau of Smoke Regulation, and upon the payment of the fees hereinafter provided, the Bureau of Smoke Regulation shall issue a permit for the construction, installation, reconstruction, alteration, or repair of such furnace, boiler furnace, stack, or other apparatus.

"In the event that any such application is rejected by the _____ _____,2/ Bureau of Smoke Regulation, the applicant has the right to appeal from his decision to the Advisory Board. Such appeal shall be made in writing to the _____,2/ Bureau of Smoke Regulation, who shall call a special meeting of the Advisory Board within three (3) days for the consideration of the matter. If a majority of the members of the Advisory Board present shall be of the opinion that the application calls for such construction, installation, reconstruction, alteration, or repair of furnace, boiler furnace, stack, or other apparatus, that there will not under reasonable conditions of operation be produced or emitted from the stack connected therewith such smoke as is herein prohibited, the decision of the_____,2/ Bureau of Smoke Regulation, shall be reversed, and the finding of the Advisory Board shall be binding upon the _____,2/ Bureau of Smoke Regulation; otherwise, the same shall be confirmed. In which latter case the fees to the Advisory Board are to be paid by appellant, who shall first give bond or make other deposit of funds for the amount of the fees provided for in Section 1 of this ordinance.

"Sec. 5. It shall be unlawful for any engineer, contractor, or other person or corporation to do the work of constructing, installing, reconstructing, altering, or repairing any furnace, boiler furnace, stack, or other apparatus connected with stack, unless the person or corporation for whom such construction, installation, reconstruction, alteration, or repair is being made has proper authority, in the form of a permit, from the Bureau of Smoke Regulation for such work.

"Sec. 6. For examination of an application for a permit for any such construction, installation, reconstruction, alteration, or repair, the Bureau of Smoke Regulation shall collect, at the time of issuing such permit, for the use of the City, a fee of _____.

"The issue and delivery by the Bureau of Smoke Regulation of any such permit shall not be held to exempt the person or corporation to whom the permit has been issued or delivered, or who is in possession of the same, or whose application has been approved, from prosecution on account of the production or emission of smoke hereby prohibited.

"Sec. 7. The _____,2/ Bureau of Smoke Regulation, shall keep in the office of the Bureau of Smoke Regulation all applications made and a complete record thereof, as well as of all permits issued. He shall also keep a record of all smoke observations on all stacks and generally of the work done by the Bureau of Smoke Regulation. All such records shall be open for inspection by the public at all reasonable times. He shall, in all matters pertaining to the enforcement of the provisions of this ordinance, report direct to _____.

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"Sec. 8. The _____,2/ Bureau of Smoke Regulation, his deputies and inspectors, shall have the right to enter, in the performance of their duties, at all reasonable hours, all premises from which smoke is being emitted or has been emitted; and any person who shall, after proper identification, deny admittance to such person or persons or interfere with him or them in the performance of his or their duties shall be liable to a fine not exceeding _____ or undergo an imprisonment in the county jail or workhouse of not more than _____, or both, at the discretion of the committing magistrate or alderman.

"Sec. 9. If any person or corporation shall violate any one or more of the prohibitions or requirements of this ordinance, the _____,2/ Bureau of Smoke Regulation, shall enter suit before any police magistrate or alderman of the City of _____, and upon conviction such person or corporation shall be subject to a fine or penalty not exceeding _____ for each and every violation thereof, and each day's violation shall constitute a separate offense, or undergo an imprisonment in the county jail or workhouse of not more than _____ _____, or both, at the discretion of the committing magistrate or alderman.

"Sec. 10. (a) Each power boiler with more than 1,500 square feet of heating surface, using coal as fuel, shall be provided with a mechanical stoker or other device or attachment approved by the Bureau of Smoke Regulation.

"Heating surface shall be construed to mean all boiler surfaces in contact with hot gases.

"(b) The minimum distance between dead plate and boiler shell for horizontal return tubular boilers shall be not less than the following, according to diameter of boiler:

Diameter of boiler, inches	Distance from dead plate to shell, inches
48 and less	30
54	32
60	34
66	34
72	36
78	38
84	38

In most cases it is desirable to have more than this minimum.

"(c) Where it is proposed to use oil or powdered coal as fuel for horizontal return tubular boilers, the height of the boiler shell above the ashpit shall be not less than 60 inches; in most cases more is desirable.

"(d) All hand-fired furnaces for stationary boilers carrying more than _____ _____6/ pounds steam pressure shall be provided with steam-air jets or other approved method of admitting auxiliary air above the grates.

"If steam-air jets are used, there shall be one such jet for each 250 square feet of heating surface or fraction thereof, and the minimum number of steam-air jets shall be three.

"(e) Boilers carrying not to exceed _____6/ pounds steam pressure shall be provided with openings to admit auxiliary air above the fuel bed, having a free air opening of not less than 3 square inches for each square foot of grate surface.

"(f) All return-tubular boiler settings, in addition to steam-air jets and auxiliary air openings, shall have such gas-mixing arches, piers, or other devices as are acceptable to the Bureau of Smoke Regulation.

6/ This will vary according to location. As a matter of fact, the minimum pressure at which steam-air jets are really effective is about 60 pounds.

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"(g) Full extension furnaces shall be used on all stationary hand-fired vertical fire-tube boilers. The arch of the extension furnace must extend 4 feet behind the grate.

"(h) Each hand-fired water-tube boiler of the highly inclined or vertical type shall have full extension furnace with an arch extending at least 4 feet back of the grate and firebrick piers or other acceptable construction installed.

"(i) Each chain-grate stoker shall have an ignition arch with minimum length equal to _____ of the length of active grate.

(Note: In the Illinois district it is the judgment of chain-grate engineers that this minimum should be 3/5 and that in no case should the length of arch be less than 5 feet. Further east 2/5 may be sufficient.)

"(j) Side inclined and front overfeed stokers installed under vertically baffled boilers may be set with flush front provided the minimum distance from grate surface to heating surface is 7-1/2 feet. If minimum distance is less than 7-1/2 feet, a full extension furnace, with arch extending 2 feet back of the grate, shall be used.

"(k) Where side inclined and front overfeed stokers are installed under horizontal return tubular boilers, full extension settings shall be used.

"(l) Portable boilers of the vertical or locomotive type shall use 'smokeless' fuel, unless such boilers are equipped with approved smoke-preventing devices which will insure 'smokeless' operation under normal working conditions.

"(m) Low-pressure heating boilers carrying not to exceed _____ 6/ pounds steam pressure and rated 2,000 square feet or more of steam radiation or 3,000 square feet or more of water radiation shall be of a satisfactory 'smokeless' type and capable of reducing the amount of smoke produced so as not to exceed the limit set by Section 3.

"(n) Low-pressure heating boilers carrying not to exceed _____ 7/ pounds steam pressure and rated below 2,000 square feet of steam radiation or 3,000 square feet of water radiation and hot-air furnaces with more than 9 square feet of grate surface, if not of a satisfactory 'smokeless' type, shall burn only 'smokeless' fuel.

"(o) All low-pressure boilers shall be provided with openings to admit auxiliary air above the fuel bed, having a free air opening of not less than 3 square inches for each square foot of grate surface.

"(p) The projected grate area of any boiler using coal as fuel shall be not less than 1/60 of the heating surface where stokers are used and 1/45 of the heating surface in hand-fired furnaces.

"(q) The area of the breeching in units not exceeding 1,000 horsepower shall be 1/5 of the grate area.

"(r) Unless the height of the flue or stack is greater than 150 feet, the breeching must not drop below the horizontal at any point from boiler to stack.

"(s) The unrestricted area through the damper on any water-tube boiler shall be not less than 1/5 of the grate area and for horizontal, return-tubular, internally fired Scotch marine or Continental-type boiler shall be not less than 25 percent in excess of the combined inside area of tubes.

"(t) All power and heating plants of over 25-horsepower capacity shall be equipped with stack of sufficient height to give a minimum of 0.25-inch draft over the fire in the furnace under normal working conditions.

7/ May vary in different States. In Pennsylvania, for example, the dividing line between high pressure and low pressure is placed at 15 pounds.

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"(u) Kent's formula, H.P. = 3.33 E$\sim$H, may be used to determine the size of the stack. For each right-angle bend in the breeching 10 feet shall be added to the height so determined.

H.P. = rated boiler horsepower,
= square feet of heating surface ÷ 10 for power boilers,
= square feet of direct radiation (rated capacity) ÷ 100 for steam-heating boilers,
= square feet of direct radiation (rated capacity) ÷ 150 for water-heating boilers,
E = effective area of stack in square feet,
= A - 0.6$\sim$A, = actual area in square feet,
E + 4 in. = inside dimensions of a square stack,
diameter of $\sim$E + 4 in. = inside diameter of a round stack,
H = height of stack in feet.

"(v) The height of the stack shall be at least 30 times its inside dimension when the height does not exceed 65 feet.

"(w) No stack to which a 'smokeless' boiler (2,000 square feet or more capacity steam radiation or 3,000 square feet or more capacity water radiation) is attached shall be less than 50 feet high above the center of the breeching connection to the stack.
offsets, constrictions, or enlargements, and shall have no openings between the breeching and the top of the stack.

"(y) The top of the stack shall extend above or be far enough away from any nearby building to avoid downdrafts.

"(z) The minimum setting heights of boilers shall be those recommended by the Stoker Manufacturers' Association and the Boiler Manufacturers Association in 1922.

"Sec. 11. Any Ordinance or part of Ordinance conflicting with the provisions of this Ordinance shall be, and the same is, hereby repealed, so far as the same affects this Ordinance."

A model smoke-abatement ordinance was adopted by the Smoke Prevention Association and published in its manual of 1938.8/ It was as follows:

Model Smoke-Abatement Ordinance

"1. There is hereby established a division in the City of _____ to be known and designated as the Smoke _____. All employees in said Smoke _____ shall be appointed according to law and shall be under the supervision and control of the Smoke _____.

"The Smoke _____ shall be charged with the inspection and control of the installation and maintenance of heating, power, and fuel-burning equipment, the prevention and abatement of smoke, the examination and approval of plans of all heating, power and fuel-burning installations, and of all smoke prevention and abatement installations installed or reconstructed in any building, location, or on any premises within the jurisdiction of the City of _____.

"2. The head of the Smoke _____ shall be an engineer qualified by technical training in the theory and practice of heating, power operation, and fuel burning. He shall also be experienced in and thoroughly familiar with the design,

8/ Manual of Ordinances and Requirements: 1938, Smoke Prevention Association, Room 1001, City Hall, Chicago, Ill.

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construction, and operation of steam boilers and furnaces and in the theory and practice of smoke prevention and abatement.

"3. No new plants nor reconstruction of any existing plants for producing power and heat, nor either of them, nor any new chimney connected with fuel-burning plants, shall be erected or maintained in the City until plans and specifications of the same have been filed in the office of and approved by the Smoke _____ and a permit issued by him for such erection, reconstruction, or maintenance. Plans and specification to be filed with the _____ shall show the amount of work and the amount of heating to be done by such plant and all appurtenances thereto - including all provisions made for the purpose of securing complete combustion of the fuel to be used and for the purpose of preventing smoke; said plans and specifications shall also contain a statement of the kind of fuel proposed to be used, and said plans and specifications shall also show that the room or apartment in which such plant shall be located is provided with doors, windows, air shafts, fans, and other means of ventilation sufficient to prevent the temperature of such room, apartment, basement, or other portions of such building, wherein such steam plant or apparatus is to be used, from rising to a point higher than one hundred and twenty degrees, Fahrenheit, and sufficient also to provide that the atmosphere of any such apartment, wherein such apparatus may be located, may be entirely changed every ten minutes. Upon the approval of such plans and specifications, a duplicate set of which shall be left on file in said office, and upon the payment of the fees as hereinafter provided, the Smoke _____ shall issue a permit for the reconstruction, erection, or maintenance of such plant. The Smoke _____ shall see that the execution of the work permitted is carried out in conformity with the plans and specifications, with special reference to the amount of space used, the size and construction of the chimney or chimneys used, the provision for the prevention of smoke, and the provisions for ventilation and for the proper temperature in the boiler room.

"4. It shall be unlawful for any person to use any new or reconstructed plant for the production and generation of heat and power, or either of them, until he shall have first procured a certificate from the Smoke _____ certifying that the plant is so constructed that it will do the work required and that it can be so managed that no dense smoke shall be emitted from the chimney connected with the furnace or fire box.

"5. The emission of dense smoke within the City of _____ from the smoke stack of any locomotive, steamboat, steam tug, steam roller, steam derrick, steam pile-driver, tar kettle, or other similar machine or contrivance, or from any open fire or from the smokestack or chimney of any building or premises, excepting for a period of six minutes in any one hour during which the fire box is being cleaned out or a new fire built therein, is hereby declared to be a nuisance and may be summarily abated by the Smoke _____ or by anyone whom he may duly authorize for such purpose. Such abatement may be in addition to the fine hereinafter provided. Any person, firm, or corporation owning, operating, or in charge or control of any locomotive, steamboat, steam tug, steam roller, steam derrick, steam pile-driver, tar kettle, or other similar machine or contrivance, or open fire of any building or premises, who shall cause or permit the emission of dense smoke within the city for the smokestack or chimney of any such locomotive, steamboat, steam tug, steam roller, steam derrick, steam pile-driver, tar kettle, or other similar machine or contrivance, or open fire from the smokestack or chimney of any building or premises so owned, controlled, or in charge of him, her, or them, except for a period of six minutes in any one hour during which the fire box is being cleaned out or a new fire being built therein, shall be deemed guilty of a violation of this section and upon conviction thereof shall be fined not less than _____ dollars nor more than _____ for each offense; and each emission of dense smoke in violation of the provisions of this section shall constitute a separate offense for each and every day on which such violation shall continue.

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"6. The fee for the inspection of plans and issuing of permits, and for the inspection of furnaces or other fuel-burning apparatus or devices and issuing of certificate, shall be as follows:

"7. Prosecutions for all violations of this ordinance shall be instituted by the _____ and shall be prosecuted in the name of the City of _____.

"The issuance and delivery by the Smoke _____ of any permit or certificate for the construction or reconstruction, or any permit for the alteration or repair, of any plant or chimney connected with a plant shall not be held to exempt any person or corporation to whom any such permit has been issued or delivered, or who is in possession of any such permit, from prosecution on account of the emission or issuance of dense smoke caused or permitted by any such person or corporation.

"8. Any person who shall violate any of the provisions of this ordinance shall be fined not less than _____ dollars nor more than _____ dollars for each offense."

In May 1949, the American Society of Mechanical Engineers published an information bulletin prepared by the Model Smoke Law Committee of its Fuels Division, entitled "Example Sections for a Smoke-Regulation Ordinance".9/ This bulletin was the result of about 7 years' work, in which all interests had opportunity to present data and opinions. The preliminary reports and the final publication of this committee's work have been studied and used as a basis for law by more than 100 cities in making changes in and adopting new smoke ordinances. The foreword of this bulletin is as follows:

"The following example sections, comments, and recommendations do not provide a completely arranged model smoke law. No single smoke law can satisfactorily meet the needs of all types and sizes of communities or provide an arrangement of words for legal purposes that would satisfy all law makers. Basic sections and information are provided to guide those developing an appropriate ordinance for their community to improve cleanliness of the air. It is to be expected that, as further experience with the control of atmospheric pollution is gained and new developments arise, these model sections may be revised.

"At the outset, it is well to recognize that all differences of opinion and all controversy relative to a 'smoke' ordinance are basically economic. The necessary compromises and agreements could be more readily reached if this were constantly kept in mind. It can be assumed that no one desires unclean air; the question is, how clean an air can the community afford? Engineering can provide it. For example, all heat and power needed could be produced electrically at one plant and then distributed electrically; the gases from this plant could be washed and purified. Steam could be distributed from one plant. Fuel could be gasified at one plant and distributed by pipe lines throughout the community. Such centralized schemes have long been adopted by many communities, as far as water and sewage are concerned, but are not ordinarily considered for the purpose of obtaining pure and healthful air because of the cost. What is considered is some economic compromise. The success and life of the ordinance depend upon the sagacity of this compromise."

The bulletin consists of 15 example sections, as follows:

Sec. 1. Definitions

Sec. 2. Creation and Organization of the Department of Smoke Regulation

9/ Obtainable from American Society of Mechanical Engineers, 29 West 39th Street, New York 18, N. Y., at a price of 50¢.

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Sec. 3. Duties of the Department of Smoke Regulation

Sec. 4. Establishment of Rules and Regulations

Sec. 5. Installation Permits and Operating Permits

Sec. 6. Annual Inspections

Sec. 7. Schedule of Fees

Sec. 8. Emission Prohibited and Standards of Measurements

Sec. 9. Equipment Dealers

Sec. 10. Entrance to Premises

Sec. 11. Appeals to Appeal Board

Sec. 12. Persons Liable

Sec. 13. Prosecutions and Fines

Sec. 14. Coordination of Departments

Sec. 15. General Provisions

The bulletin also includes general comments and explanations on many of the sections. From section 8, "Emission Prohibited and Standards of Measurements," the following is quoted:

"No person shall cause, suffer, or allow to be emitted into the open air from any fuel-burning equipment, internal combustion engine, premises, or open fire, smoke the shade or appearance of which is equal to or darker than No. 2 of the Ringelmann Chart, excepting:

"(a) Smoke the shade or appearance of which is equal to but not darker than No. 2 of the Ringelmann Chart for a period or periods aggregating 4 minutes in any 30 minutes;

"(b) Smoke the shade or appearance of which is equal to but not darker than No. 3 of the Ringelmann Chart for a period or periods aggregating 3 minutes in any 15 minutes, when building a new fire or when breakdown of equipment occurs such as to make it evident that the emission was not reasonably preventable.

"For the purpose of grading the shade or appearance of smoke, the Ringelmann Chart, as now published and used by the U. S. Bureau of Mines, which is hereby made a part of the ordinance by reference, shall be the standard.

"No person shall cause, suffer, or allow to be emitted into the open air from any fuel-burning equipment or premises, or to pass a convenient measuring point nearest to the stack outlet, dust in the gases to exceed 0.85 lb. per 1,000 lb. of gases, adjusted to 50 percent excess air for products of combustion, excepting that for fuel-burning equipment or premises constructed subsequent to the effective date of this ordinance, a dust-collecting efficiency of not more than 85% shall be required for special dust-separating equipment, and that for fuel-burning equipment or

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premises constructed prior to the effective date of this ordinance, a dust-collecting efficiency of not more than 75% shall be required for special dust-separating equipment. The limitations given shall be waived during periods when breakdown of equipment occurs such as to make it evident that the emission was not reasonably preventable. The amount of solids in the gases shall be determined according to the Test Code for Dust-Separating Apparatus of the American Society of Mechanical Engineers, revised and amended to date, which is hereby made a part of this ordinance by reference.

"No person shall cause, suffer, or allow to be emitted into the open air from any fuel-burning equipment, internal combustion engine, railroad locomotive, vehicle, premises, open fire, or stack, soot or fumes that are a detriment to the property of others or that are a nuisance to any person not being therein or thereupon engaged."

The report also states that local conditions may make it advisable to include in this Section special provisions concerning the permissible emission of smoke and dust from locomotives, vehicles, Bessemer converters, blast furnaces, open-hearth furnaces, etc.

In May 1950, a subcommittee of the Smoke Prevention Association of America, Inc., on "Standards for Emission of Solids from Chimneys" recommended that the emission of solids to the atmosphere from the chimney of any boiler plant should not exceed the quantities given in the following table:

Steam-generated, (a) pounds per hour	Solids emission, (b) pounds per hour
10,000	22
20,000	45
30,000	67
40,000	90
50,000	112
60,000	134
80,000	180
100,000	224
150,000	284
200,000	334
300,000	419
400,000	489
500,000	552
600,000	609
800,000	709
1,000,000	798
1,500,000	1,200
2,000,000	1,600
3,000,000	2,400
4,000,000	3,200

(a) "Steam-generated" shall be the average hourly output of all units connected to the chimney for that continuous 4-hour period during which the average output is the greatest, expressed as the equivalent of steam containing 1,000 British thermal units per pound.

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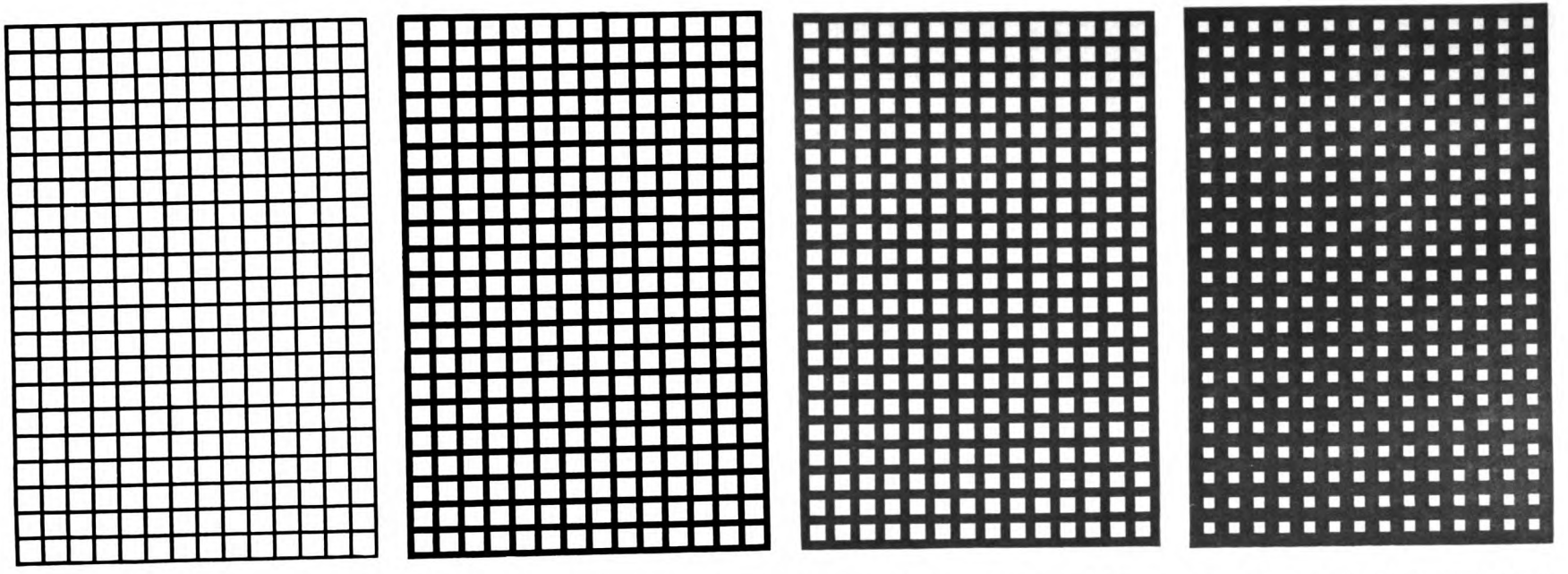

1. Equivalent to 20 percent black 2. Equivalent to 40 percent black 3. Equivalent to 60 percent black 4. Equivalent to 80 percent black

Figure 1. - Ringelmann's scale for grading the density of smoke.

Hang smoke chart on a level with the eye, about 50 feet from observer, as nearly as possible in line with chimney. Glance from smoke to chart and note corresponding number, recording same and time of observation. Repeat observations at one-fourth or one-half minute intervals. From these records the average density may be determined for each hour, or for each day. No smoke is recorded as No. 0. 100 percent black smoke is recorded as No. 5. Experienced observers often record in half chart numbers.

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(b) "Solids emission" quantities shown may be exceeded for a period of, or periods aggregating, 2 hours in any continuous 24 hours during which the gas-swept passages of the boilers are being cleaned.

The amount of smoke permitted from a stack by the model ordinance is based upon its shade or relative clearness to blackness as seen by the eye. For example, a smoke that was 60-percent black would be a gray made by mixing black and white in proportions of 6 to 4. To establish gray colors on the basis of percentage of blackness, the Ringelmann smoke chart was devised (fig. 1). From a practical standpoint, it has been found that only four gray colors between clearness and blackness need be used - 20, 40, 60, and 80 percent black as shown in the figure. For convenience, these colors are numbered 1, 2, 3, and 4; clearness is 0, and 100 percent black is 5. Only a little training is needed to establish these colors in the observer's mind. The chart is hung at eye level, about 50 feet away, and about in line with the stack to be observed. The smoke is compared with the different panels of the chart, which at 50 feet appear as various shades of gray. During this training period it is sometimes helpful to have an experienced observer check with the novice. Complete information as to reading smoke by this method is given in Bureau of Mines Information Circular 6888.10/ After a few trials, an observer learns to read the smoke without the help of the chart, and it is no longer necessary for him to mount it for observation. This scheme of reading smoke makes possible not only the determination of when any chosen shade of smoke is made or exceeded but also the determination of the average smoke produced over a period of time, which often is of considerable importance. Occasionally "smokes" are emitted to the air that are not made up of black particles. The Ringelmann shade scheme is not satisfactorily applicable for such smokes. The ordinance of the County of Los Angeles covers this by adding to the shade limitation of No. 2 on the Ringelmann chart, "or of such opacity as to obscure an observer's view to a degree equal to or greater than does smoke----" of the No. 2 shade limitation.

Many objections have been raised to this method of judging the amount of smoke coming from a stack, such as the diameter of the stack, the cloud and wind conditions, and the human element in judging shade, all of which are considered to affect the result. These comments and objections, however accurate, become inconsequential when the entire purpose of the readings is considered. The purpose is not merely to fine some violator because smoke of a certain shade has been emitted, about which it may be argued just what percentage of blackness occurred or how many black particles were emitted, but the purpose is to lessen smoke emission and to cooperate to the fullest extent in making a neighborhood cleaner. When a stack gives "dense smoke," as judged by any inspector, work should be done to improve conditions. The smoke-chart scheme is proving effective and is simple, and none more practical has yet been devised for the purpose.

Most cities use the Ringelmann chart for making observations. Some cities, however, use the umbrascope, which consists of an eyepiece and a cylinder about 4 inches long and 1-1/2 inches in diameter containing clouded glasses hinged to swing in and out of the field of vision and covering half the circle; through the other half, which is left open, an area of the smoke can be seen. By this means the smoke can be compared directly with the clouded glass, which is considered to eliminate some of the human factor in judging grays. The great disadvantage of this method is its general tediousness and slowness. An observer cannot be expected to hold the unbrascope to his eye and manipulate glasses all day long, and his effectiveness in abatement work is greatly lowered because of the relatively few observations he can

10/ Kudlich, Rudolf, Ringelmann Smoke Chart: Bureau of Mines Inf. Circ. 6888, 1936, 3 pp.

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make. The observer usually finds that he can judge the smoke better without the instrument and is tempted to lay it aside. Although a person not actually experienced in smoke reading may feel that more accuracy can be obtained from direct comparison with a colored glass, tests and experience show differently. The colored-glass schemes might be used in training an observer, and in acute cases, where it is necessary to take the violator to court, some might consider the glass comparison as good evidence. However, courts in general accept the evidence of a trained inspector that he saw smoke in violation of an ordinance.

The earlier ordinances and abatement work were chiefly concerned with "smoke," usually black that the inspector or the general public could readily see coming from a stack. Hand firing predominated, and the carbonaceous particles were considered the nuisance. There was not so much fly ash from boilers, and such particles were more or less accepted. People did not become particularly excited over sand and dust until the many paved roads caused much of it to disappear. Along with road development came the big increase in stoker-fired equipment, which tends to throw out ash rather than carbon particles. The above A.S.M.E. section 8, and the report of the subcommittee of the S.P.A.A. both of recent origin, recognize this development and set a definite limitation on "dust" or solid particles of the fly-ash type.

Figure 2 shows the A.S.M.E. dust limitations and the efficiency of the dust collector required to meet the section for different dust inlet loadings. No collectors would be required for domestic stokers or commercial underfeed or traveling stokers operating at low loads, say below about 30 pounds of coal per square foot of grate per hour. For new installations, a dust-collector efficiency of 85 percent would be required only for most pulverized fuel-burning equipment and for some stokers operating at extremely high rates; lower dust-collecting efficiencies could be used for much of the commercial fuel-burning equipment. Although the dust limitations of the subcommittee of the S.P.A.A. are based upon steam production, they can be compared to those of the A.S.M.E. - based on flue gas loading - by calculations that include estimated plant efficiencies. For a steam production of 1,000,000 pounds per hour or more, the flue gas loading limitation would be about 0.58 pound per 1,000 pounds of flue gas at 50 percent excess air. The A.S.M.E. limitations shown in figure 2, which are technically independent of plant size, range from 0.85 pound to, say, 3 pounds per 1,000 pounds of flue gas at 50 percent excess air. In actual practice, the larger plants ordinarily have the higher flue-gas loadings and fall at the right part of the curve (fig. 2), the smaller plant falling at the left. Therefore, the S.P.A.A. subcommittee limitations are much more restrictive for the large plants as compared to those of the A.S.M.E. However, for the small plants the reverse is true. The limitation of 0.58 pound of the S.P.A.A. committee rises as steam production drops, being about 1.47 pounds for, say, a production of 100,000 pounds of steam per hour or lower. This is much higher than the 0.85 pound of the A.S.M.E., which ordinarily applies to the small plant.

Approaching the solid-particle air-contaminant problems from the standpoint of nonferrous, steel, gray-iron, and electric-iron metallurgical industries, the County of Los Angeles developed the following ordinance limitations:

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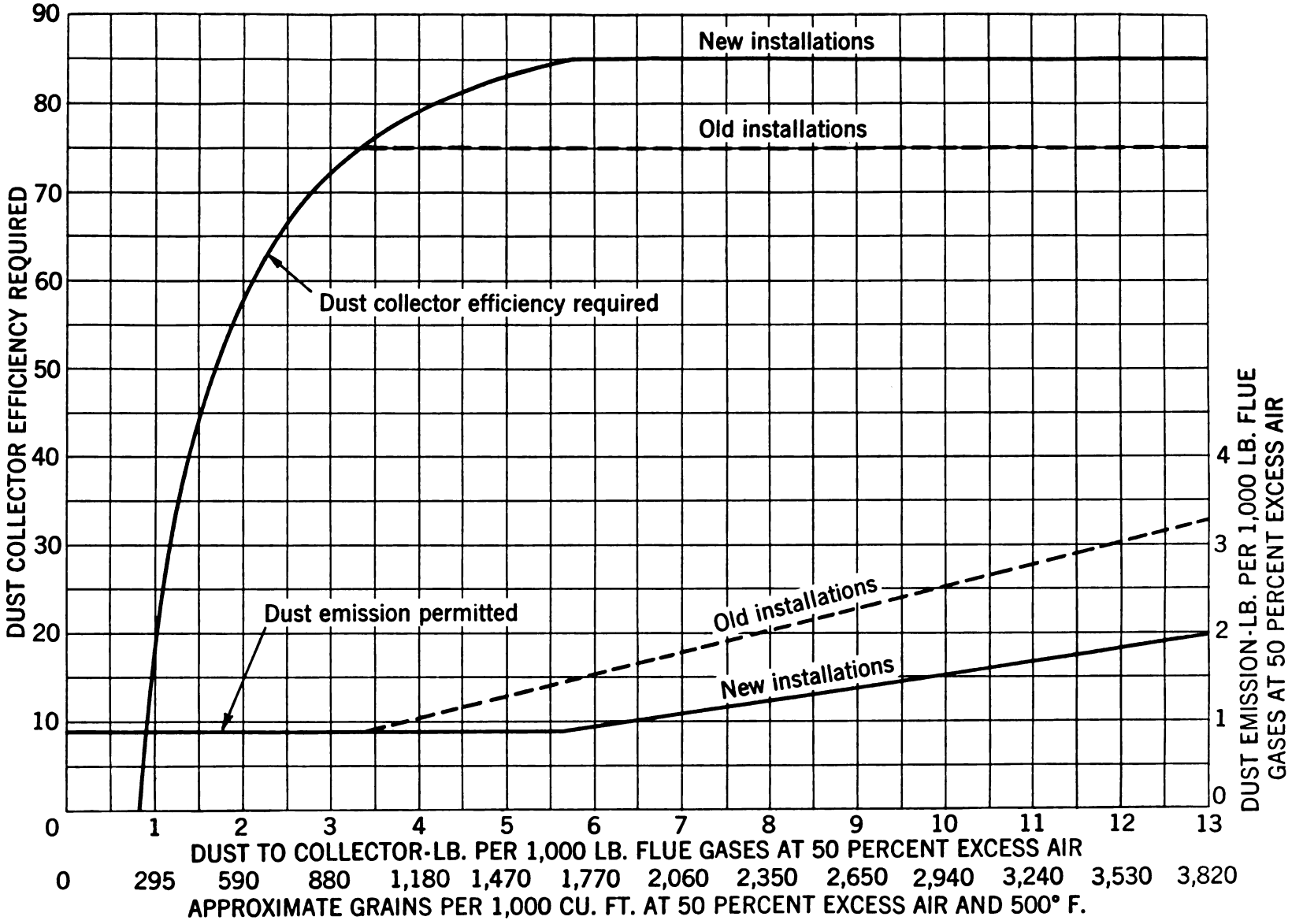
New installations
Old installations
Dust collector efficiency required
Dust emission permitted
Old installations
New installations
DUST COLLECTOR EFFICIENCY REQUIRED
DUST EMISSION-LB. PER 1,000 LB. FLUE GASES AT 50 PERCENT EXCESS AIR
DUST TO COLLECTOR-LB. PER 1,000 LB. FLUE GASES AT 50 PERCENT EXCESS AIR
APPROXIMATE GRAINS PER 1,000 CU. FT. AT 50 PERCENT EXCESS AIR AND 500° F.
0 10 20 30 40 50 60 70 80 90
0 1 2 3 4
0 1 2 3 4 5 6 7 8 9 10 11 12 13
0 295 590 880 1,180 1,470 1,770 2,060 2,350 2,650 2,940 3,240 3,530 3,820

Figure 2. - A.S.M.E. dust limitations and the efficiency of the dust collector required for different dust inlet loadings.

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Maximum allowable discharge per hour of solids

Process weight per hour, lb.	Allowable discharge per hour, lb.	Process weight per hour, lb.	Allowable discharge per hour, lb.	Process weight per hour, lb.	Allowable discharge per hour, lb.	Process weight per hour, lb.	Allowable discharge per hour, lb.
50 ...	0.24	1,300 ...	3.26	3,500 ...	5.52	8,500 ..	9.03
100 ...	0.46	1,400 ...	3.40	3,600 ...	5.61	9,000 ..	9.36
150 ...	0.66	1,500 ...	3.54	3,700 ...	5.69	9,500 ..	9.67
200 ...	0.852	1,600 ...	3.66	3,800 ...	5.77	10,000 ..	10.0
250 ...	1.03	1,700 ...	3.79	3,900 ...	5.85	11,000 ..	10.63
300 ...	1.20	1,800 ...	3.91	4,000 ...	5.93	12,000 ..	11.28
350 ...	1.35	1,900 ...	4.03	4,100 ...	6.01	13,000 ..	11.89
400 ...	1.50	2,000 ...	4.14	4,200 ...	6.08	14,000 ..	12.50
450 ...	1.63	2,100 ...	4.24	4,300 ...	6.15	15,000 ..	13.13
500 ...	1.77	2,200 ...	4.34	4,400 ...	6.22	16,000 ..	13.74
550 ...	1.89	2,300 ...	4.44	4,500 ...	6.30	17,000 ..	14.36
600 ...	2.01	2,400 ...	4.55	4,600 ...	6.37	18,000 ..	14.97
650 ...	2.12	2,500 ...	4.64	4,700 ...	6.45	19,000 ..	15.58
700 ...	2.24	2,600 ...	4.74	4,800 ...	6.52	20,000 ..	16.19
750 ...	2.34	2,700 ...	4.84	4,900 ...	6.60	30,000 ..	22.22
800 ...	2.43	2,800 ...	4.92	5,000 ...	6.67	40,000 ..	28.3
850 ...	2.53	2,900 ...	5.02	5,500 ...	7.03	50,000 ..	34.3
900 ...	2.62	3,000 ...	5.10	6,000 ...	7.37		
950 ...	2.72	3,100 ...	5.18	6,500 ...	7.71		
1,000 ...	2.80	3,200 ...	5.27	7,000 ...	8.05		
1,100 ...	2.97	3,300 ...	5.36	7,500 ...	8.39		
1,200 ...	3.12	3,400 ...	5.44	8,000 ...	8.71		

Where process weight falls between figures stated, values of allowable discharge per hour are interpolated. In no case is particulate matter in excess of 40 pounds per hour allowed to emit from any one source.

Process weight is defined as total weight of raw materials or materials entering process (not weight of finished product). Solid fuels charged are considered as part of process weight, but liquid and gaseous fuels and combustion air are not.

In continuous operation average rate of feed is used.

In batch operation total batch weight divided by operating time of a batch cycle determines process weight per hour.

Regardless of process weight involved, no discharge greater than 40 pounds per hour is permitted.

The solids are defined as follows:

Fumes are solid particles commonly generated by the condensation of vapors of solid matter after volatilization from the molten state. They may be generated by sublimation, distillation, calcination, or chemical reaction whenever such processes create air-borne particles.

Dusts are solid particles released to the air by natural forces or generated by mechanical processes such as crushing, grinding, milling, drilling, demolition, bagging, sweeping, and shoveling.

Unlike smoke readings, methods of determining the quantity of dust being emitted from a chimney are complicated and expensive.11/ Special equipment and men trained

11/ Test Code for Dust-Separating Apparatus of the American Society of Mechanical Engineers, 29 West 39th Street, New York 18, N. Y.

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to make this type of test with the necessary technical calculations must be used. Some cities, owing to lack of funds, are unable to handle such testing and prefer to put the dust problem on a simple "nuisance" basis.

There are many air contaminants other than smoke and dust. Sulfurous gases are quite common, coming from the combustion of fuels and also from various metallurgical processes. The tonnage of resulting sulfuric acid released into the air is astounding.12/ 13/ 14/ 15/ There has been little legislation against such gases. The County of Los Angeles has attacked the problem by limiting, by ordinance, the concentration at the point of discharge, as follows: "Sulfur compounds (calculated as SO_2), 0.2 percent by volume". Other contaminants, to date, have ordinarily been placed on a nuisance or detrimental basis. There is much work yet to be done on identification of and possible legislation against miscellaneous air contaminants coming from various industrial processes.

The ordinance should make possible the issuance of regulations as to design of fuel-burning equipment. At this point the application of fuel technology is needed. Such regulations should include rules for such items as type of stokers, setting heights, loading, heat releases per cubic foot of combustion space per hour, breechings, stack heights, and smoke indicators.16/ Among good examples of these regulations are those of Hudson County, N. J., Chicago, Ill., and Washington, D. C. These differ somewhat in details. The Rules and Regulations, as issued by the City of Washington, D. C., are given in full; they illustrate the extent and nature of such regulations.

FOREWORD

"This booklet is published for the convenience of citizens who are concerned with the installation of fuel-burning equipment. These rules and regulations are based on what has been found to be good practice and are designed to afford protection to the owner in securing a satisfactory job and to place manufacturers and contractors on an equal footing. It is not contemplated that they be retroactive in the sense that the owners of all existing equipment be immediately required to make changes to conform to them.

"It should always be borne in mind that the primary purpose of this Division is to secure 'smokeless' operation.

H. K. KUGEL,
Smoke Regulation Engineer.

12/ Barkley, J. F., The Sulfur Problem in Burning Coal: Bureau of Mines Tech. Paper 436, 1928, 7 pp.

13/ Burdick, L. R., and Barkley, J. F., Effect of Sulfur Compounds in the Air on Various Materials: Bureau of Mines Inf. Circ. 7064, 1939, 9 pp.

14/ Burdick, L. R., and Barkley, J. F., Sulfur in the Products of Combustion of Fuels: Bureau of Mines Inf. Circ. 7065, 1939, 23 pp.

15/ Burdick, L. R., and Barkley, J. F., Concentration of Sulfur Compounds in City Air: Bureau of Mines Inf. Circ. 7066, 1939, 14 pp.

16/ Barkley, J. F., and Morgan, R. E., Fuel-Burning Equipment Dimensions Required By Smoke-Abatement Ordinances: Bureau of Mines Inf. Circ. 7557, March 1950, 19 pp.

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SECTION I. - GENERAL INFORMATION

1. Smoke

"(a) Smoke is the result of the incomplete combustion of any fuel. The primary cause is the failure to secure a sufficient amount of air intimately mixed, at the proper temperature, with the combustible gases that are given off by the burning of the fuel. The secondary cause is carelessness, ignorance, and indifference in the firing and operation of the fuel-burning equipment.

"(b) Smoke can be prevented by -

1. Using a fuel suited to the equipment.
2. Keeping the equipment in good condition.
3. Firing carefully and intelligently.
4. Using automatic fuel-burning equipment wherever possible.

"(c) Smoke is an indication of waste. Prevention results in more uniform heating, a saving in fuel, and consequently reduced costs.

"(d) Smoke has associates which also pollute the air. These include coke (partly burned fuel), ash, and the sulfur gases. Little has been done to minimize them in small installations, but they contribute to the damage and discomfort of living in cities and require serious consideration.

"(e) The Division of Smoke Regulation and Boiler Inspection is glad to advise the public in the proper method of firing as well as the use of proper fuels in the equipment which they have. It hopes for the cooperation of all in its efforts to improve conditions in the District of Columbia.

2. Smoke Law

(Public, No. 279, 74th Cong. (S. 2034))

AN ACT To prevent the fouling of the atmosphere in the District of Columbia by smoke and other foreign substances, and for other purposes.

"Be it enacted by the Senate and House of Representatives of the United States of America in Congress assembled, That no person shall cause, suffer, or allow dense smoke to be discharged from any building, stationary or locomotive engine, or motor vehicle, place, or premises within the District of Columbia. All persons participating in any violation of this provision, either as proprietors, owners, tenants, managers, superintendents, captains, engineers, firemen, or motor-vehicle operators, or otherwise, shall be severally liable therefor. The owners, lessees, tenants, occupants, and managers of every building, or place in or upon which a locomotive or stationary engine, furnace, or boiler is used shall cause all ashes, cinders, rubbish, dirt, and refuse to be removed to some proper place, so that the same shall not accumulate, nor shall any persons cause, suffer, or allow cinders, dust, gas, steam, or effensive or noisome odors to escape or to be discharged from any such building, or place, to the detriment or annoyance of any person or persons not being therein or thereupon engaged.

"Sec. 2. The Commissioners of the District of Columbia are hereby authorized and directed to make and promulgate reasonable classifications and regulations for the installation and operation of combustion and all other devices susceptible for use in such manner as to violate the purposes of this Act, and the said Commissioners may from time to time alter, amend, or rescind such regulations and promulgate such amended or additional regulations as they may in their discretion deem necessary.

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"Sec. 3. Enforcement of this Act shall be upon information by the Corporation Counsel in the police court of the District of Columbia. Any person convicted of violating this Act or any regulation of the Commissioners made hereunder shall be punished by a fine not to exceed $500 for each and every such offense.

"Sec. 4. The Commissioners of the District of Columbia shall be responsible for the enforcement of this Act and may direct the Police Department, the Health Department, or any officer or employee of the government of the District of Columbia to perform such service as necessary in connection with such enforcement. Appropriations are hereby authorized to be made to carry out the purposes of this Act, and the Commissioners of the District of Columbia are authorized to include in their annual estimates provision for the expenses incident to such purposes and for personnel subject to the limitations of the Personnel Classification Act of 1923.

"Sec. 5. All provisions of the Act approved February 2, 1899 (30 Stat. 812, ch. 79, sec. 5), which are inconsistent with this Act are hereby repealed.

"Approved, August 15, 1935.

3. Definitions

"(a) Person. - The word 'person' signifies and includes firms, corporations, companies, receivers, associations, executors, administrators, trustees, guardians, or agents.

"(b) Dense smoke. - The term 'dense smoke', as used in section 1 of the Act, shall be defined as smoke equal to or greater than No. 3 of the Ringelmann chart as prepared and approved by the United States Bureau of Mines.

"(c) Cinders, dust, fly ash. - The terms 'cinders, dust' as used in section 1 of the Act shall be defined the same as the term 'fly ash,' which shall be considered to be all solids including coke (partly burned fuel), cinders, dust, and soot, formed as a result of the combustion of fuel, which are carried in the gas stream so as to reach the external air.

"(d) Stack. - Stack means any chimney or smokestack or other structure whether of brick, tile, concrete, metal, or other material or a combination of any of these materials intended for the emission of the products of combustion from the burning of any fuel or material. Smokestacks commonly known as smoke-jacks attached to locomotive roundhouses shall be deemed stacks and a part of whatever locomotive is beneath them for the time being.

"(e) Breeching. - Breeching means any smoke flue or connection leading from a boiler or furnace to a stack.

"(f) Horsepower. - Horsepower shall be construed to mean rated boiler horsepower (hp.) and shall be figured on the basis of 10 square feet of boiler heating surface per horsepower.

"One boiler horsepower shall be considered equal to 140 square feet of equivalent direct steam radiation or 224 square feet of water radiation.

"(g) Boiler-heating surface. - Boiler-heating surface shall be construed to mean all boiler surfaces in contact with hot gases.

"(h) Equivalent direct radiation. - One square foot of equivalent direct radiation (E.d.r.) shall be considered equal to the heat emission of 240 B.t.u. per hour for steam and 150 B.t.u. per hour for hot water.

"(i) Power boiler. - Power boiler shall be construed to mean any boiler carrying over 150 pounds steam pressure.

"(j) Heating boiler. - Heating boiler shall be construed to mean any boiler carrying not over 15 pounds steam or 30 pounds water pressure, or temperatures not exceeding 250° F.

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"(k) Fuel agreement. - A fuel agreement is a written agreement entered into between the owner of a building or plant and the Division of Smoke Regulation and Boiler Inspection whereby the said owner in consideration of a permit being issued for the installation of a certain boiler or furnace agrees to burn only certain specified fuels.

SECTION II. - ADMINISTRATION

1. Duties

"(a) The Smoke Regulation Engineer shall be responsible for the administration of the act to prevent the fouling of the atmosphere in the District of Columiba by smoke and other foreign substances, Public, No. 279, Seventy-fourth Congress, approved August 15, 1935, and these regulations issued thereunder.

"(b) He shall issue all permits, certificates, and notices under these regulations; keep applications, permits, plans, violations, complaints, and other records on file for such period as is deemed necessary or as may be directed by the Commissioners of the District of Columbia.

"(c) He shall examine the plans of all new buildings, stacks, and incinerators and plans for the alteration of existing buildings in order to insure that they are in accordance with these regulations.

"(d) He shall also examine the application and plans for the construction, installation, reconstruction, alteration, or repair of any boiler, furnace, incinerator, stack, or other apparatus connected with the stack and, subject to the requirements of these rules and regulations, issue an installation permit.

"(e) The smoke inspectors, when so directed, shall investigate complaints and make inspections and observations of smoke conditions in the District of Columbia. They shall inspect the installation of all equipment for which a permit has been issued and see that the work is done in accordance with regulations and the plans as approved. They shall make daily written reports of all inspections, violations, and complaints.

"(f) Any member of the staff of the Smoke Regulation Engineer shall be authorized to perform such other duties as may be assigned by the said engineer or by the Commissioners of the District of Columbia.

2. Additional Requirements for Obtaining Building Permits

"(a) When application is made and plans are filed with the inspector of buildings for a permit for the erection of a new building, stack, or incinerator, or the alteration of an existing building, the application and plans shall be submitted to the Smoke Regulation Engineer, together with a plan and elevation in duplicate showing the location of the stack or stacks in reference to adjoining buildings. The plans and application shall be certified in writing by the Smoke Regulation Engineer before a building permit is issued.

"(b) Such approval shall not be construed to indicate approval of the structural design of any structure or of any of the requirements of other codes of the District of Columbia.

3. Application for Installation Permits and Certificates of Inspection

"(a) No person shall construct, install, reconstruct, alter, or repair any boiler, water heater, furnace, oven, stoker, oil burner, gas burner, apparatus to burn pulverized coal, or other apparatus connected with the boiler, breeching, or

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stack, or any apparatus which may cause dense smoke, cinders, dust, gas, steam, or offensive or noisome odors to be discharged into the air, or make changes or additions to the heating system, domestic hot-water load, process work, or other load whereby the load on the boiler is materially increased, until he shall have made application and obtained an Installation Permit from the Smoke Regulation Engineer. The application shall be made out on the form provided, showing the nature of the work to be done, the size and make of the boiler or other equipment, the size and make of the burner or stoker, the fuel to be used, the size of the breeching and stack, and other information pertinent to the installation. Repairs which do not increase the capacity of such boiler or furnace or do not involve any alteration or addition to such boiler, furnace, or other apparatus, or which do not involve any alteration in the method of smoke prevention may be made without a permit. Applications for an installation permit for any boiler, furnace, incinerator, stack, or other apparatus connected with the stack for use in a private residence shall not be required until further notice.

"(b) Applications must be accompanied by a sketch or drawing in duplicate showing the location of the boiler in the boiler room with the distance from the various walls and exits, the size and location of openings for admission of air to boiler room, the size and location of breeching including damper and clean-out doors, and the method of installation of stoker, oil burner, or other equipment.

"(c) Upon the approval of any application and the payment of the proper fees to the collector of taxes the Division of Smoke Regulation and Boiler Inspection shall issue an installation permit for the work shown on the application.

"(d) The Smoke Regulation Engineer, or one of his inspectors, shall inspect, after completion, all boilers, furnaces, stacks, or other apparatus for which an installation permit has been issued, and if such be found to be in accordance with the plans and specifications and the information given on the application a certificate of inspection shall be issued.

"(e) No person shall use or cause to be used any new, remodeled, or reconstructed boiler, furnace, incinerator, stack, or other apparatus connected with the stack, unless said person shall have a certificate of inspection, showing that the construction or reconstruction is in compliance with the plans and specifications submitted when making application for an installation permit.

"(f) The issuance by the Smoke Regulation Engineer of any installation permit or certificate of inspection for the construction, installation, reconstruction, alteration, or repair of any boiler, furnace, incinerator, stack, or other apparatus connected with the stack shall not be held or construed to exempt any person to whom such installation permit or certificate of inspection may have been issued from prosecution on account of the emission of smoke and the products of combustion which are prohibited.

"(g) The Smoke Regulation Engineer and his assistants shall have the right to enter, in the performance of his or their duties, at all reasonable hours, all premises from which smoke, cinders, dust, gas, or odors are being emitted or have been emitted, or where the construction, installation, reconstruction, alteration, or repair of any boiler, furnace, incinerator, stack, or other apparatus connected with the stack is taking or has taken place, and it shall be unlawful for any person to deny admittance to said engineer or his assistants or to interfere with him or them in the performance of his or their duties.

"(h) The application for and subsequent issuance of an installation permit by the Smoke Regulation Engineer shall not be construed to indicate approval of the strength or safety of any building or stack or of any of the requirements of the codes which are enforced by the building, plumbing, or electrical inspectors or the fire marshal, nor shall it relieve anyone from the necessity of obtaining a permit for work covered by these divisions.

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"(i) Fees, as hereinafter provided, shall be paid to the collector of taxes of the District of Columbia and a receipt presented to the Division of Smoke Regulation and Boiler Inspection. Fee for installation permit and certificate of inspection shall be paid at the same time. Fees for heating boilers shall be based on equivalent direct radiation capacity. Fees for power boilers shall be based on horsepower rating, to be determined either by dividing (1) the boiler heating surface by 10 or (2) the manufacturers output rating in pounds of steam per hour by 34.5; the larger rating shall be used for setting the fee.

"Fees for the installation of boilers, furnaces, and hot water supply boilers:

	Permit	Certificate
Heating boilers, each:		
Less than 1,200 sq. ft. of steam or 1,800 sq. ft. of water	$2.00	$3.00
1,200 to 5,000 sq. ft. of steam, 1,800 to 7,500 sq. ft. of water	3.00	5.00
5,001 to 25,000 sq. ft. of steam	5.00	10.00
Over 25,000 sq. ft. of steam	10.00	15.00
Boilers when installed in each unit of an apartment building, each	.75	.75
Power boilers, each:		
Less than 50 horsepower	4.00	6.00
51 to 250 horsepower	5.00	10.00
251 to 500 horsepower	10.00	15.00
501 to 1,000 horsepower	15.00	25.00
Over 1,000 horsepower	25.00	35.00
Miniature boilers, each	3.00	5.00
Warm air furnaces, each:		
Less than 100,000 B.t.u. output	2.00	3.00
Over 100,000 B.t.u. output	3.00	5.00
Hot water-supply boilers, each:		
100 to 500 gallons per hour capacity	2.00	3.00
Over 500 gallons per hour capacity	3.00	5.00
Above based on 100° temperature rise.		
Unclassified apparatus	3.00	5.00

"The above fees shall include the installation of stokers, oil burners, gas burners, grates, and similar appliances when installed as an integral part of and simultaneously with such boilers, furnaces, and hot water-supply boilers under the same permit.

"Fees for installation of stokers, oil burners, gas burners, grates, and similar appliances when not installed as an integral part of and simultaneously with boilers, furnaces, and hot water-supply boilers under the same permit:

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	Permit	Certificate
Heating boilers, each:		
Less than 1,200 sq. ft. of steam or 1,800 sq. ft. of water	$2.00	$3.00
1,200 to 5,000 sq. ft. of steam, 1,800 to 7,500 sq. ft. of water	3.00	5.00
5,001 to 25,000 sq. ft. of steam	5.00	10.00
Over 25,000 sq. ft. of steam	10.00	15.00
Power boilers, each:		
Less than 50 horsepower	4.00	6.00
51 to 250 horsepower	5.00	10.00
251 to 500 horsepower	10.00	15.00
501 to 1,000 horsepower	15.00	25.00
Over 1,000 horsepower	25.00	35.00
Miniature boilers, each	3.00	5.00
Warm air furnaces, each:		
Less than 100,000 B.t.u. output	2.00	3.00
Over 100,000 B.t.u. output	3.00	5.00
Hot water-supply boilers, each:		
100 to 500 gallons per hour capacity	2.00	3.00
Over 500 gallons per hour capacity	3.00	5.00
Above based on 100° temperature rise.		
Miscellaneous equipment: The installation of steam-air jets, blowers, draft controls, apparatus for collection of fly ash, etc., which affects the operation of the boilers	2.00	3.00
Boiler furnaces: Rebuilding or changing boiler furnace or heating system involving a major change in capacity or combustion space	2.00	3.00

"(j) Permits shall be valid and in force for a period not exceeding 6 months, except that work started within this time and continuously under construction for more than 6 months may proceed to completion under authority of the original permit.

"(k) A permit to install or relocate any boiler, furnace, stack, incinerator, or other apparatus connected with the stack shall be issued only after the inspector of buildings has permitted installation or relocation of such equipment.

"(l) If the work called for in the installation permit shall be conducted in violation of any of the provisions of these regulations or in any other manner than shown on the original plan and application the Smoke Regulation Engineer shall give notice of such violation to the contractor, his foreman, or representative on the job, through one of the smoke inspectors. Such notice shall fix a time which is reasonable and sifficient in the opinion of the Smoke Regulation Engineer to make the necessary changes, and if such work is not put in conformity with the regulations within the time mentioned, then he shall revoke the permit. Before such a permit can be lawfully reissued the contractor or owner shall have changed the work so that it conforms to the original plan.

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SECTION III. - REQUIREMENTS WHEN PLANS FOR NEW BUILDINGS ARE BEING SUBMITTED

"1. The stack must be of sufficient height and cross-sectional area to provide the necessary draft for the proper operation of the boiler and shall comply with all requirements of the building code.

"2. The top of the stack must be of such a height in relation to adjoining buildings so that the gases discharged will not become a nuisance to adjacent buildings and so that down drafts will be prevented.

"3. A clean-out door must be provided at the base of stack.

"4. The stack must be so located in reference to the boiler as to permit of a well-designed breeching of adequate area and having a minimum number of bends or turns and with the shortest practicable length.

"5. The boiler room must be of sufficient height to allow for the installation of boilers of sufficient capacity to carry the full required load and having ample combustion space in the boiler furnace. Sufficient headroom must be provided for installation of a breeching of proper design and to allow for accessibility to manholes and valves connected to boiler.

"6. Sufficient floor space must be provided to allow for the proper operation of the boiler, including the use of shovel and firing tools, removal of boiler tubes and making necessary repairs, cleaning boiler tubes, furnace fire-box, and combustion chambers and to allow for easy access to furnace doors and other openings in and about walls of boiler settings or furnaces and for cleaning and removal of soot and ash from the breeching and stack.

"7. Sufficient exits, properly located, must be provided to allow egress in case of emergency.

"8. The fuel-storage space shall be partitioned off from the boiler room proper and be so located as not to interfere with the efficient operation of the boiler. Where a different kind of coal is required for a hot-water heater, provision must be made for separate storage. Consideration must be given to having a satisfactory place for delivering coal and removing ashes from the building so that dirt and dust may be kept to a minimum.

"9. Provision must be made to permit the unrestricted admission to the boiler room of a sufficient amount of air to secure smokeless combustion of the fuel and properly to ventilate the room in which the fuel-burning equipment is located.

"10. Incinerators to be used in connection with the new building must be provided with a separate stack and be built in conformity with the incinerator code.

SECTIÓN IV. - REQUIREMENTS BOILER- AND FUEL-BURNING EQUIPMENT

1. General

"(a) Power boilers shall be equipped with underfeed stoker, apparatus to burn pulverized coal, oil burner, or gas burner.

"(b) Heating boilers and hot water-supply boilers having an equivalent direct radiation rating of more than 1,200 square feet of steam radiation or 1,800 square feet of water radiation shall be equipped with underfeed stoker, oil burner, or gas burner.

"(c) Heating boilers and hot water-supply boilers having an equivalent direct radiation rating of less than 1,200 square feet of steam radiation or of 1,800 square feet of water radiation shall burn coke, anthracite, or shall be equipped with underfeed stoker, oil burner, or gas burner.

"(d) Low-pressure steam boilers, when mechanically fired, shall be equipped with a low-water cut-off, or similar arrangement, so located as to automatically cut

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off the fuel supply in case the water level falls to a point not lower than the bottom of the water glass. The water-gage glass shall be set as follows: Steel heating boilers of the fire-tube type, the lowest permissible water level shall be (a) for single-pass type the same as called for in paragraph 291 of the power-boiler regulations, (b) for multipass types the top row of tubes shall be completely submerged when the water is at the lowest reading in the water-gage glass. All of the water connections shall be nonferrous pipe and fittings with a cross at each right-angle turn.

"(e) Gravity-feed magazine boilers designed exclusively for the burning of coke or anthracite may be installed in all sizes, subject to the requirements and approval of the Division of Smoke Regulation and Boiler Inspection.

"(f) Every boiler shall be constructed and installed in accordance with the provisions of these regulations, the Boiler Inspection Regulations of the District of Columbia where they apply, and the Boiler Code of the American Society of Mechanical Engineers, Section I to VII, inclusive, and Amendments and Interpretations thereto, made and approved by the Council of the Society to date. Every boiler shall bear the A. S. M. E. symbol and number, and the manufacturer's data report form shall be provided when requested.

2. Stokers

"(a) Underfeed stokers shall have minimum furnace heights as follows:

Rating - square feet steam radiation	1,200 to 2,499	2,500 to 6,999	7,000 to 10,999	11,000 to 13,999	14,000 to 17,499	17,500 to 20,999	21,000 to 25,000
Equivalent horsepower	10-18	19-50	51-80	81-100	101-125	126-150	151-175
	Inches	Inches	Inches	Inches	Inches	Inches	Inches
Compact type	36	42	48	54	60	66	72
L. F. B. type	48	54	60	66	72	78	84
H. R. T.	-	42	48	54	60	66	72
Cast iron	36	42	48	54	60	66	-

Abbreviations: L. F. B. = locomotive firebox; H. R. T. = horizontal return tubular.

NOTE. - In using above table, take rated boiler horsepower or radiation, whichever is the larger.

"(b) All dimensions are from the stoker dead plate (or dump grate) of the crown sheet (or equivalent) of the boiler. On down-draft boilers the water grates shall be considered the equivalent of the crown sheet, unless they are removed.

"(c) The above figures are considered to be minimum dimensions and shall be increased wherever the boiler is to carry an overload or has peak-load conditions to be met.

"(d) Stokers designed for anthracite will be given special ruling.

"(e) Horizontal-water-tube heating boilers in sizes up to 25,000 square feet of steam radiation shall, when horizontally baffled, have the same setting heights as compact-type boilers; when vertically baffled they shall have the same setting heights as locomotive firebox-type boilers. For boilers above 25,000 square feet use table below.

"(f) The minimum furnace heights of all other types and sizes of water-tube boilers equipped with underfeed stokers, to be operated up to 150 percent rating, shall be as follows:

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Measurement of setting height	Type of boiler	Multiple retort				Single retort			
		Min.		Pref. min.		Min.		Pref. min.	
		Ft.	in.	Ft.	in.	Ft.	in.	Ft.	in.
Floor line to bottom of header above stoker.	Horizontal, all sizes	11	0	13	0	9	0	11	0
Floor line to center of mud drum.	Incl. H. M. D., all sizes	7	6	8	6	6	6	8	6
Floor line to top of mud drum.	Incl. V. M. D., all sizes	6	0	7	0	5	0	7	0
Floor line to center of mud drum.	Vert. H. M. D., all sizes	3	6	5	0	3	6	5	0
Floor line to top of mud drum.	Vert. V. M. D., 150 hp.	4	6	5	0	4	6	5	0
Do.	Vert. V. M. D., 250 hp.	5	6	6	0	5	6	6	0
Do.	Vert. V. M. D., 500 hp.	6	0	6	6	6	0	6	6

Abbreviations: Incl. = inclined; vert. = vertical; H. M. D. = horizontal mud drum; V. M. D. = vertical mud drum; min. = absolute minimum; Pref. min. = preferred minimum, that is, the heights recommended.

"(g) For power boilers equipped with underfeed stokers, to be operated at more than 150 percent rating, special ruling shall be obtained from the Division of Smoke Regulation and Boiler Inspection. Design of all stoker installations shall be submitted to the Division of Smoke Regulation and Boiler Inspection for approval.

"(h) Stokers shall be installed so that the bottom of the boiler water leg will be suitably protected. Boiler doors shall be of sufficient size and so located that ash and clinker can be easily removed without disturbing the fuel bed.

"(i) On all stoker installations a clean-out door shall be provided in the breeching and at the base of the stack and an accessible damper in the breeching fitted with a handle and quadrant, or the equivalent, so arranged that it can be clamped in position and be conveniently operated.

"(j) When stokers are rated in terms of coal fed per hour or square feet of equivalent direct steam radiation (E. D. R.), such rating shall be based on nut and slack coal with a heat content taken as not greater than 14,000 B. t. u. per pound for bituminous coal and 12,400 B. t. u. for buckwheat anthracite, with a combined boiler and stoker efficiency of not to exceed sixty (60) percent for stoker capacities up to seventy-five (75) pounds of coal per hour and not to exceed sixty-five (65) percent for stoker capacities over seventy-five (75) pounds per hour.

"A certified rating sheet based on the above together with all other necessary information shall be supplied for every stoker, subject to the approval of the Smoke Regulation Engineer.

"An allowance of not less than thirty-five (35) percent shall be provided for piping and pick-up.

"(k) The rating of any stoker shall not be less than the rating of the boiler with which it is to be installed, except that where the boiler is to be operated in excess of its rating the stoker shall be of sufficient capacity adequately to carry such overrating.

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3. Pulverized Coal

"(a) When pulverized coal is to be used as fuel, the required combustion space for all boilers up to 500 horsepower and having refractory walls shall be determined on the basis of a maximum heat liberation of 20,000 B.t.u. per cubic foot of combustion space per hour. For larger boilers and other types of walls, maximum heat liberation shall be determined for each individual case. An acceptable method of collecting fly ash from the stacks or breechings of all pulverized-coal plants shall be provided. Design of all pulverized-coal installations shall be submitted to the Division of Smoke Regulation and Boiler Inspection for approval.

4. Oil

"(a) When oil is to be used as a fuel, the required combustion space shall be determined on a basis of a maximum heat liberation of 30,000 B.t.u.'s per cubic foot of combustion space per hour, except that for specially designed boilers burning No. 2 oil, where the boiler, burner, and controls are assembled, tested, and shipped as a complete unit, the combustion space may be determined according to the individual design of the equipment and its demonstrated performance.

"(b) Each oil burner shall be approved by the Underwriters Laboratories or other nationally recognized inspection board or laboratory and shall bear a metal plate permanently attached, giving this approval and the grade of oil for which approved. In addition, each burner shall have a metal plate permanently attached, giving the manufacturer's name and the model or size number of the unit, so that it can be identified as the burner for which a permit has been issued. Complete information, including an installation manual and a rating sheet, shall be supplied for each make of burner. Failure to provide these plates or data shall be sufficient grounds for refusal to issue an installation permit.

"(c) Where oil of grade 6 is to be used, provision shall be made for heating and automatically maintaining the temperature of the oil at not less than 180° F. Electric preheaters shall be provided for starting when there is no steam available.

"(d) Each boiler fired with oil of grade 2 or 3 and of capacity in excess of 25 horsepower, 4,250 sq. ft. of steam radiation, or 6,800 sq. ft. of water radiation, and each boiler burning grade 5 or 6 oil, shall have one or more self-closing explosion doors located in the boiler breeching and in the setting of brick set boilers. Such doors, when located within 7 feet of the firing floor or of any platform or walkway, shall be provided with substantial metal deflectors to divert the blast of exploding gas, so that it will not constitute a hazard.

"(e) Plate-type dampers shall not be installed in oil-fired boilers or breechings, except that where required for automatic control such damper may be used, provided it has at least 15 percent clearance and is equipped with means for manual operation and locking.

"(f) Packaged steam generators consisting of a boiler and burner equipped with all controls designed as a unit, with all the air for combustion mechanically introduced and having mechanical draft, may be approved for installation subject to the following specific requirements plus all other applicable regulations:

"1. Use of solid fuel in such units is prohibited.

"2. Each boiler and burner shall be an integral unit complete with all the necessary controls and ready for operation when service connections are made.

"3. Each unit shall be completely assembled and tested by the unit manufacturer before shipment and a record of such operating test shall be provided.

"4. Each unit shall be built in accordance with the American Society of Mechanical Engineers' boiler code and shall include protection against ignition failure,

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flame failure, excess pressure, excess flue-gas temperature, low water and furnace explosion, and shall provide accessibility for inspection and cleaning.

"5. Each unit shall be approved by the Underwriters Laboratories or other nationally recognized inspection board or laboratory and shall bear a metal plate permanently attached indicating such approval and specifying the grades of oil for which the burner is approved.

"6. Each unit shall have a metal plate permanently attached, giving the manufacturer's name, the model or size number of the unit, and the guaranteed output of the boiler in pounds of steam per hour as determined by tests conducted in accordance with American Society of Mechanical Engineers' power test code. The duration of test shall not be less than 4 hours.

"7. In any case in which a unit has not been approved by the Division of Smoke Regulation and Boiler Inspection prior to receipt of application for permit, the applicant shall submit manufacturer's installation and service manual, drawings and specifications, including heating surface and record of American Society of Mechanical Engineers' performance tests for each unit proposed to be installed.

"8. The sizes of stacks shall be as shown in the following table. In all other respects, stacks shall conform to all the provisions of article 7 of these regulations:

Horsepower, manufacturers' ratings	Round stack diameter, inches	Square stack	
		Firebrick-lined, inches inside	Standard flue lining, inches
10	12		13 x 13
15	12		13 x 13
20	12		13 x 13
30	12		13 x 13
40	14		18 x 18
50	14		18 x 18
60	14		18 x 18
70	16		18 x 18
80	16		18 x 18
100	18		18 x 18
125	18		18 x 18
150	20		20 x 20
200	24	22 x 22	
250	24	22 x 22	
300	28	26 x 26	
350	28	26 x 26	
400	32	30 x 30	
450	32	30 x 30	
500	32	30 x 30	

Stack heights shall not be less than 45 feet above ground level for power boilers and 35 feet for heating boilers, but consideration must be given to the location of the stack in reference to other buildings, as provided in article 7. Steel stack and breeching shall be welded throughout.

"9. After submission of the above required data, the chief engineer shall, at his discretion, make such additional investigation as he deems necessary in order to establish that the unit is built and will operate in compliance with the requirements of these regulations and the Boiler Inspection regulations.

"10. When material changes in design or construction of a unit previously approved are made, all pertinent data shall be submitted as called for above.

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5. Net Load

"(a) 'Net load' shall be construed to mean all radiation used for heating purposes, exclusive of piping, and reduced to the equivalent of direct cast-iron radiation in a temperature of 70° F., which shall be calculated on a basis of 240 B.t.u. per square foot per hour for steam and 150 B.t.u. per square foot per hour for water.

"(b) Any generator, coil in firebox, indirect heater, or other device attached to boiler, used for heating water for domestic purposes, shall be included in net load and shall be calculated in equivalent direct radiation in accordance with the rules of the Heating and Piping Contractors National Association, as shown in their Net Load Recommendations Manual.

"(c) The net-load capacity of heating boilers shall be the net-load recommendations of the Heating and Piping Contractors National Association, revised and amended to date.

"(d) Or, where available, the net-load capacity may be obtained on the basis of the American Society of Heating and Ventilating Engineers Standard Code for Rating Steam Heating Boilers. Such boiler rating shall be determined as a result of tests made for the manufacturer by a disinterested party or laboratory acceptable to the Smoke Regulation Engineer.

"(e) The equivalent direct radiation (E.D.R.) rating of cast-iron boilers shall be obtained by adding not less than thirty-five (35) percent to the net-load rating; for steel heating boilers the E. D. R. ratings as determined by the Code of the Steel Heating Boiler Institute (S. H. B. I.) shall be used.

6. Clearance Around Boilers and General Requirements

"(a) All boilers or boiler settings shall have at least three (3) feet clear space on each side, in the rear, and in front of oil burner or stoker, except that in existing buildings this may be reduced by the Smoke Regulation Engineer, if after inspection it is found that it is impractical to obtain such clearances. In addition, sufficient space must be provided to remove boiler tubes.

"(b) Where replacement or additional installations of boilers are made in existing buildings the minimum height of the boiler room shall be such as to provide not less than six (6) inches clear space above the highest point of any valve or other fitting when it is at maximum opening or stems and levers at their greatest height. In new or reconstructed buildings not less than seven (7) feet shall be provided between the top of the boiler proper and the ceiling or other obstruction, except that in single installations of self-contained boilers a minimum clearance of at least three (3) feet may be provided between the highest point of any valve or fitting and the ceiling or other obstruction.

"(c) When a boiler, oil burner, or stoker is installed in a pit more than 18 inches in depth, masonry or metal steps with a metal handrail shall be provided for access to the pit, and a metal railing not less than 36 inches in height shall be provided entirely around the pit.

7. Stacks

"(a) Power boilers having more than 120 square feet of boiler heating surface shall have a stack of sufficient height or shall have an induced-draft fan to give a minimum draft of 0.20 inch of water over the fire in the furnace under normal working conditions. No such stack shall be less than 45 feet above the ground line, unless gas is used as fuel.

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"(b) Size and height of stacks for power boilers shall be based on approved chimney practice, taking into consideration draft losses in boiler and breeching.

"(c) Heating plants having boilers with a net-load rating of more than 1,200 square feet of steam radiation or 1,800 square feet of water radiation shall have a minimum draft of 0.15 inch of water over the fire in the furnace under peak-load conditions.

"(d) With the exception of gas-fired boilers or heaters, the following table shall in general be used as a guide. Stack sizes are inside dimensions, and plans should be so marked. The sizes given are for one boiler and are minimum.

"(e) Where boiler capacity is in excess of ratings shown in table, stack shall be figured on the same basis as for power boilers.

"(f) If it is impractical to obtain the height of stack as indicated an induced-draft fan may be used, subject to the approval of the Division of Smoke Regulation and Boiler Inspection, provided the discharge from the stack will not become a nuisance to neighboring buildings.

"(g) The provisions of the act of June 1, 1910, 36 Stat. 452, as to stacks shall continue in full force and effect.

Stack table for heating boilers

Rectangular flue lining				Round flue	Minimum 1/
Boiler rating, square feet of radiation		Actual inside dimensions	Standard flue lining	Actual inside diameter	Height above grate
Steam	Water				
		Inches	Inches	Inches	Feet
To 450	To 720	8 x 12	8 x 13	10	35
800	1,280	12 x 12	13 x 13	12	35
1,000	1,600	12 x 16	13 x 18	15	40
1,500	2,400	16 x 16	18 x 18	18	40
2,000	3,200	18 x 18	20 x 20	18	45
2,500	4,000	17 x 21	20 x 24	20	50
3,000	4,800	21 x 21	24 x 24	22	55
3,500	5,600	21 x 21	24 x 24	22	55
4,000	6,400	22 x 22	-	24	60
5,000	8,000	24 x 24	-	26	60
6,000	9,600	26 x 26	-	28	65
7,000	11,200	26 x 28	-	28	65
8,000	12,800	28 x 28	-	30	70
9,000	-	30 x 30	-	32	70
10,000	-	32 x 32	-	34	75
12,500	-	34 x 34	-	38	75
15,000	-	36 x 36	-	40	80
17,500	-	38 x 38	-	42	85
20,000	-	40 x 40	-	44	90
25,000	-	42 x 42	-	46	100

1/ Height must be increased if breeching is more than ten (10) feet long or has more than one bend.

NOTE. - For each additional boiler add not less than seventy-five (75) percent of the area and ten (10) feet to the height as given in table.

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"(h) The inside walls of each stack shall be smoketight, vertical, free from offsets or constrictions, and have a clean-out opening with a tightly fitted door. All stacks shall conform to requirements of the building code.

"(i) The top of any stack shall extend sufficiently above the roof of the building of which it is a part, and shall extend above or be far enough away from any nearby building to prevent down drafts or the creation of a nuisance by the discharge of smoke or the gases of combustion.

"(j) Where an existing stack is so located that it will constitute a nuisance to the occupants of a building about to be built, the owner of the new building shall be required either to extend the existing stack or make other provisions to meet the approval of the Division of Smoke Regulation and Boiler Inspection.

"(k) Boilers or furnaces located in separate rooms or buildings shall each have a separate stack or flue lining in the stack.

"(l) The tops of boiler stacks shall not be covered with caps or screens.

"(m) Stacks shall be as nearly square or round as possible. Where the stack is rectangular or oval in cross section, the greatest dimension shall not exceed twice the smallest.

8. Breechings

"(a) Breechings shall be as nearly square or round as possible. Where the breeching is rectangular or oval in cross section the greatest dimension shall not exceed twice the smallest. The minimum radius of all bends shall not be less than the width of breeching at point where bend occurs.

"(b) Breeching shall be as short and straight and free from bends or curves, drops below horizontal, or other restrictions as possible

"(c) Where separate hot-water heater is to be provided the breeching may be connected directly to the stack but below the entrance of the boiler breeching.

"(d) Every breeching shall be provided with sufficient clean-out openings having tightly fitted doors and of sufficient size so that all parts of breeching may be easily cleaned.

"(e) The draft loss in the breeching shall be taken into consideration in the design of the boiler plant and stack.

"(f) A lay-out of breeching must accompany application for permit

9. Air to Boiler Rooms

"(a) Each boiler or furnace room shall have an opening or openings to the external air to provide sufficient air for proper combustion, as may be determined by the Smoke Regulation Engineer.

10. Smoke Indicators

"(a) All new fuel-burning plants having more than 300 square feet of boiler heating surface or its equivalent shall be equipped with smoke indicators, mirrors, or similar devices, approved by the Division of Smoke Regulation and Boiler Inspection, to enable the firemen easily to observe smoke conditions from the boiler room at all times, unless the top of the stack is readily visible to the firemen.

"(b) Where oil of grade 5 or 6 is used, an approved electric eye-type smoke alarm shall be installed, subject to the approval of the chief engineer, Smoke Regulation and Boiler Inspection, in an accessible position. Such instrument shall be so connected either to shut down the oil burner in the event of dense smoke being made or be provided with a loud bell or horn capable of being heard outside of the boiler

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room and above the noise of other equipment. It shall have a dial or gage calibrated to indicate variations in smoke density. It shall be maintained in condition to operate and shall not be shut off at any time while the boiler is in service.

11. Vertical Boilers

"(a) Vertical fire-tube boilers shall be installed only upon entering into a fuel agreement unless such boilers are equipped with oil or gas burners. Only one boiler of this type containing not more than 250 square feet of heating surface shall be permitted in a plant.

12. Scotch Marine Boilers

"(a) Scotch marine boilers shall be installed only upon entering into a fuel agreement unless such boilers are equipped with oil or gas burners. If equipped with oil burner, a dutch oven shall be provided. An underfeed stoker may be permitted where it is specially designed for this type of boiler. When hand-fired only one boiler of this type containing not more than 250 square feet of heating surface shall be permitted in a plant.

13. Warm-Air Furnaces

"(a) Warm-air furnaces having 7 square feet or more of grate surface shall be equipped with underfeed stoker, oil or gas burner, approved by the Division of Smoke Regulation and Boiler Inspection, unless owner of building or plant signs a fuel agreement.

"(b) Warm-air furnaces having less than 7 square feet of grate surface shall burn coke, anthracite, or low-volatile coal, or shall be equipped with underfeed stoker, oil or gas burner, approved by the Division of Smoke Regulation and Boiler Inspection.

"(c) Heating plants having warm-air furnaces with a total of 7 square feet or more of grate surface shall have a stack of sufficient height to give a minimum draft of 0.15 inch of water over the fire in the furnace under normal working conditions.

14. Water Heaters

"(a) Water heaters shall burn coke or anthracite or shall be equipped with underfeed stoker, gas or oil burner.

"(b) When a heating boiler is equipped with an underfeed stoker and a hand-fired water heater is used, a separate bin shall be provided for fuel for the heater.

"(c) Hot-water heaters used in connection with a tank of less than 100 gallons capacity shall not require an installation permit.

15. Incinerators

"(a) Incinerators shall be built in accordance with the incinerator code and shall have a stack separate from that of the boiler or furnace.

"(b) The stack shall terminate in a substantially constructed spark arrester made so as to project above the top of the stack and having openings not larger than one-fourth inch.

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16. Portable Boilers and Contractors' Equipment

"(a) After January 1, 1937, no person or corporation shall operate any portable boiler, steam shovel, portable crane, derrick, hoist, road roller, tar kettle, asphalt kettle, or any other similar portable equipment capable of emitting smoke until he shall have signed a fuel agreement and obtained a permit from the Division of Smoke Regulation and Boiler Inspection. All such existing equipment shall use coke or anthracite, or be equipped with oil burners approved by the Division of Smoke Regulation and Boiler Inspection.

"(b) The Division of Smoke Regulation and Boiler Inspection shall have authority to attach identification tags to all such equipment.

"(c) After January 1, 1938, equipment of the above-mentioned type shall be operated by internal-combustion engine or electric motor; tar and asphalt kettles shall use only oil burners.

17. Process Furnaces, Stills, and Other Apparatus

"(a) Detailed description and drawings of any furnace, still, or other apparatus, capable of causing smoke, cinders, dust, gas, or odors, showing the design, amount, and kind of fuel to be used, etc., shall be submitted to the Division of Smoke Regulation and Boiler Inspection for approval.

18. Rubbish Burning

"(a) No person constructing, tearing down, or wrecking any building or structure shall burn tar paper, refuse, or rubbish in an open fire at the site.

"(b) No person shall burn any garbage, refuse, rubbish, or other combustible material in an open fire.

SECTION V. - PENALTY

1. Failure to Comply

"(a) Failure to comply with any of these rules and regulations or any provision thereof, shall subject such person or persons to the penalty prescribed by the act of Congress approved August 15, 1935.

"(b) Sec. 3. *** Any person convicted of violating this act or any regulation of the Commissioners made hereunder shall be punished by a fine not to exceed $500 for each and every such offense".

SMOKE ABATEMENT AT PLANTS

Smoke must actually be abated, of course, at each individual plant. There are a number of reasons why the individual plant owner, from his own standpoint, should not produce smoke. Smokeless combustion gives the following results:

(a) Improved combustion efficiency. Smoke is unburned fuel; it frequently is accompanied by invisible unburned gases. With the lower furnace temperatures (so often found in smaller boilers) an appreciably greater amount of fuel must be used when smoke is produced. In general, the cost of the elimination of smoke with improved combustion efficiency will be covered amply by the decreased cost of fuel. The usual operating engineer likes to use as little fuel as possible to accomplish the needed results. The total fuel bill, however, is an expenditure that is rather

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difficult to analyze and judge. Many owners or superintendents will pay a fuel bill without much question or with only a few repeated cautions; but if the operating engineer wishes to spend a little money for an instrument or for some device or construction that will lower the fuel bill somewhat, or if he should happen to have increased stoker and furnace maintenance because of carrying better furnace temperatures and combustion efficiencies, he is apt to be open to considerable questioning and perhaps criticism. He may decide that it is simpler to bury the matter in the fuel bill.

(b) Improved boiler conditions. The production of smoke coats the boiler heating surfaces with soot, lowering its efficiency in taking the heat from the gases and thereby raising the fuel bill. The draft loss through the boiler increases. There is also increased cost or labor for cleaning the boiler heating surfaces.

(c) Improved breeching and stack conditions. Soot from the smoke may accumulate in the boiler breeching and stack, thereby lowering the draft to a point where it is difficult to carry the boiler load. Such soot has been known to catch fire, which might result in more serious difficulties.

(d) Cleaner immediate surroundings. Although the smoke from the stack of a building usually makes a neighboring building dirty, it may also to some extent make the building having the stack dirty, thus increasing cleaning costs. Elimination of the smoke improves the good will of the neighborhood toward the owner.

(e) Better neighborhood tone. The character of the immediate neighborhood is improved by the elimination of smoke. This tends to improve building income.

(f) Freedom from troubles with the smoke inspector. Where there are smoke regulations, smoke production causes at least intermittent trouble with inspectors, possibly leading to convictions and fines. This may be one of the strongest arguments that can be presented to the individual mind.

Whenever a fuel not inherently smokeless is burned, smoke may readily be produced; it is necessary to take care of all factors that may be helpful in lowering smoke emission. It is desirable for each fireman to understand the cause of smoke and to have a few fundamental ideas about combustion. When a fuel burns, it is uniting with the oxygen of the air. To unite with this oxygen, which comprises about 20 percent of the air, the fuel must be hot. Therefore, for anything to burn it must be kept hot enough, enough air must reach it, and, as a practical matter, it must have enough room in which to burn. When a piece of coke burns, the oxygen unites with it at its surfaces, its hotness being maintained by the heat of the burning. When a piece of coal burns, the action is a little different. As it heats it gives off some smoky gas or volatile matter. A piece of paper when warmed will give off considerable volatile matter before it bursts into flame. Stack smoke is the result of such volatile matter leaving the furnace unburned. It did not unite with oxygen for such causes as never being hot enough, cooling too quickly, or never being mixed with oxygen. It might not have gotten hot enough because too much was given off quickly; it might have gotten hot but was cooled down immediately on account of striking some cold surfaces of the boiler; it might not have been mixed with air because of insufficient draft, lack of air openings, or lack of turbulence. With such fundamental thinking, it is possible for one to watch a smoke-producing fire and soon decide what is the difficulty. The fuel-burning equipment must be at least reasonably well adapted to the fuel being burned. It should provide for a feeding of the fuel that does not cause too much smoky gas to be given off at one time. There must be enough space for the flames to develop. Ample overfire draft should be available. The equipment should be kept in good condition, especially as to undersirable air leakage.

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Probably the chief cause of smoke production in the ordinary plant is the way it is operated. However well planned the equipment, much smoke may be produced because of faulty operation. Many buildings have boiler rooms so situated that the fireman has no idea what is happening at the stack outlet. One of the biggest helps in eliminating smoky operation is a means for the fireman to know at all times exactly how much smoke is being emitted from the stack. There are many devices for this purpose. A simple one is an ordinary mirror so placed that the top of the stack can be seen. Periscopes of various types may be used. There are available on the market instruments that give a daily record of the smoke emission, throw colored lights on and off, and ring bells. One very effective scheme, from the standpoint of getting quick action from the operator, consists of blowing a raucous horn when the smoke density passes a chosen point. Smoke-indicating devices also are quite helpful to a fireman in teaching him what produces smoke.

Many boilers are equipped with the underfeed type of stoker. On this stoker, the coal is pushed upward toward the burning fuel bed above. The coal is gradually heated as it approaches the hot fuel bed and slowly gives off its volatile matter, which is readily ignited by the hot fuel bed and burned. By the time the coal reaches the fuel bed, it has become mostly burning coke. This fuel-burning principle is ideal and can be applied quite effectively, but as a practical matter considerable smoke may be produced because of undesirable operating conditions. Manhandling the fuel bed, thereby stirring up green coal into the hot zones, usually releases a great deal of volatile matter that does not burn. Such operations as feeding the coal too rapidly or shoveling in some extra coal by hand to bring up the load quickly, cleaning the fires rather carelessly, disturbing the fuel bed unduly, improper adjustment of the air supplying auxiliaries, poor draft regulation, and stopping the stoker and air supply when the fuel bed contains much warmed coal that continues to give off volatile matter - all result in smoke. Sometimes considerable smoke may be produced by poorly chosen coal. In general, these causes apply to other types of equipment as well.

With the ordinary hand-fired flat grate, two methods of firing can be considered - the spreading and the coking. When the spreading method is used, a small amount of coal is fired at a time and is spread over only a part of the grate. If the fuel bed is burning down evenly, the coal may be spread evenly from front to rear through one of the firing doors at a time. If there are thin spots in the fuel bed the coal may be spread over these spots. In this way the fuel bed is only partly covered with fresh coal at any one time. The fresh coal heats rapidly and gives off its volatile or smoky gases. The air for burning, carrying the oxygen, flows through the fuel bed. The oxygen combines with the hot coke of the fuel bed wherever they meet. Some of the oxygen generally gets through the fuel bed through holes and may be used to burn the unburned gases above the fuel bed. When there is a large volume of smoky or unburned gases, it is usually necessary to let some air in over the fuel bed through special openings to provide enough oxygen.

When the coking method is used, considerable coal is fired at the front of the grates, forming a mound of fresh coal. When this coal is nearly or entirely coked and has given off most of its volatile matter, it is shoved back over the back part of the grates, leveling the hot fuel bed. The fresh coal heats rather slowly and gives off its volatile matter slowly. The volatile matter has good opportunity to burn when it meets the hot gases coming from the hot coke at the back of the grates. It is sometimes desirable to let in a little air at the firing doors. The burning of coke after it is pushed back is completed as in the spreading method. The coking method usually

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gives less smoke difficulties, but does not give as lively a fire. Much study and care are required to hand fire bituminous coals smokelessly.17/

When undesirable smoke is produced under reasonable conditions or operation of the equipment available, its satisfactory elimination frequently can be achieved with help from overfire jets. Overfire jets are of three general types: (1) steam-air jets, by which air is injected at high velocity into the furnace by means of a steam jet; (2) blower jets, in which air under pressure is provided for the jets by blowers; (3) steam jets, in which steam is injected into the furnace to provide turbulence only. The choice of type, design, number, positioning, and pressures usually can be determined only by study of each individual plant. Research on jets has resulted in engineering curves and tables for proper installation.18/ The pressure of steam for steam-air jets or for steam-turbulence jets depends various factors, the distance of penetration required into the furnace being an important one. For many cases, pressures of about 50 to 100 pounds can be used. Objections have been raised to the use of steam because excessive amounts are required and because of noise. The quantity of steam used by jets can be calculated fairly accurately, the quantity varying with the nozzle diameter, the steam pressure, and the percent of the time they need to be in operation.18/ The quantity used is best considered on the basis of its percentage of the total steam produced by the boiler. This may range from a negligible percent up to, say, 2.5 for properly installed and operated jets. To offset this loss, there is a gain in combustion efficiency. The elimination of the objectionable noise of a steam-air jet requires careful planning. If the air inlets to the jets are open to the air at the boiler front, unsatisfactory noise may be produced and the operators are not apt to use the jets. However, if the air is piped from the stoker wind box or is taken from channels in the settings, the noise disappears. Bringing the air through the setting also preheats it to some extent.

A change in the furnace arrangement to improve combustion is sometimes the best solution to the problem of abatement of smoke. It can often be done at low cost. For example, in the common, horizontal, return-tubular boiler setting, an arch placed back of the bridge wall will cause the gases to travel away from the shell, and better use is made of the combustion space for burning. The problem of improvement is one of determining a better arrangement for each installation that gives the required time, turbulence and temperature for good combustion. Sometimes increased setting height is needed to provide enough combustion space. Smoke-abatement ordinances in many cities specify required furnace dimensions.19/ Owing to the many factors at each installation that affect furnace-arrangement design, only experienced engineers should be given such problems.

Fly ash (dust), unlike smoke, is continually leaving the furnace, even under the best conditions. The amount varies greatly with the load or the pounds of coal burned per square foot of grate area. For example, on one underfeed installation, increasing the fuel rate per square foot of grate area about three-fourths, or from 23 to 40.5 pounds, raised the amount of fly ash, expressed as a percentage of the weight of the total coal fired, about 3.8 times, or from 0.73 to 2.80 percent. The actual weight of

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17/ Barkley, J. F., Questions and Answers for the Coal Fireman: Bureau of Mines Question and Answer Handbook 1, 1941, 17 pp.

18/ Engdahl, R. B., and Major, W. S., Application of Overfire Jets to Prevent Smoke from Stationary Plants: Bituminous Coal Research, Inc., Tech. Report No. VII, August 1947, 912 Oliver Building, Pittsburgh 22, Pa. 25 cents.

19/ See footnote 16 on page 14.

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the fly ash leaving the boiler per hour increased about 6.8 times, or from 82.4 to 556.9 pounds.20/ Much of the fly ash, particularly the larger sizes, may never reach the stack outlet. An appreciable percentage can be caught in various passes in the boiler and in properly placed cinder traps. At any place where the velocity of the gases drops, some fly ash will be deposited, as the speed of fall of the heavier particles is enough to separate them from the gases. Collecting-hopper arrangements may be provided in back chambers and passes in the boiler; some installations provide an ejector that returns fly ash to the combustion chamber for further burning. Simple forms of baffle-type cinder catchers may be installed in the breeching and arrangements made to dump them regularly; where more can be expended for fly-ash removal, various more complicated forms of cinder catchers are commercially available.21/

Where too much fly ash is permitted to accumulate in one place, such as along the bottom of the breeching, it may lift suddenly and go out the stack, creating an immediate nuisance. Keeping all passages clean is a great help. Fly ash will settle at the base of the stack; the amount will be affected by the velocity of gases up the stack. Air openings at the base of the stack or below the breeching entrance may prevent considerable settling of fly ash. Opening the door at the base of the stack usually causes accumulated fly ash to lift. Where it is necessary to open the door to clean out the fly ash, the use of water will help. A simple circular-pipe water spray may be installed at the base of the stack below the point where the breeching enters, and the fly ash may be wet down just before it is removed. Sometimes a simply designed spray is installed above the breeching entrance for intermittent use when the boiler tubes are blown. Such a spray lowers the temperature of the flue gases and will thereby lower the draft available from the stack. The water picks up sulfurous gases and becomes acidified, and considerable water vapor goes into the stack gases. Various corrosion problems may develop if the water is allowed to flow continuously. Only expensive, specially developed spray equipment should be so used. However, for intermittent operation at rather long intervals such equipment is kept dry by the flue gases most of the time and has given satisfactory service for help in tube blowing.

The emission of sulfurous gases from fuel-burning equipment can be abated by using fuels of lower sulfur content. This is not always economically feasible, however. Such gases can be removed from the products of combustion by gas-washing equipment, but this is ordinarily too costly to install, maintain, and operate; in general, it is not considered appropriate or practicable. The abatement of gases, odors, fumes, and dusts from metallurgical and special process plants requires individual study by qualified personnel. Much progress is now being made along these lines.

Regardless of equipment, the project of successful smoke abatement ends with the human factor. The operators must be trained to handle their particular equipment, and owners and operators must become enthused with the idea of abating smoke and fly ash. City air pollution abatement is a long, hard problem requiring the expenditure of funds, continuing pressure, and work year after year. The results of good work include the satisfaction of having aided humanity to better living conditions.

20/ Barkley, J. F., Fly-Ash Data from the Federal Central Heating Plant: Combustion, December 1937, pp. 32-33.

21/ Barkley, J. F., Reduction of Fly-Ash Emission From Chimneys: Bureau of Mines Rept. of Investigations 3472, September 1939, 8 pp., and Miller, Carl E., What Can The Small Plant Do About Fly Ash?: Bituminous Coal Research, Inc., 912 Oliver Building, Pittsburgh 22, Pa. 25 cents.

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